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[Management Brief]

Electrofishing Effort Required to Estimate Biotic Condition in Southern Idaho Rivers

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Abstract.—An important issue surrounding biomonitoring in large rivers is the minimum sampling effort required to collect an adequate number of fish for accurate and precise determinations of biotic condition. During the summer of 2002, we sampled 15 randomly selected large-river sites in southern Idaho to evaluate the effects of sampling effort on an index of biotic integrity (IBI). Boat electrofishing was used to collect sample populations of fish in river reaches representing 40 and 100 times the mean channel width (MCW; wetted channel) at base flow. Minimum sampling effort was assessed by comparing the relation between reach length sampled and change in IBI score. Thirty-two species of fish in the families Catostomidae, Centrarchidae, Cottidae, Cyprinidae, Ictaluridae, Percidae, and Salmonidae were collected. Of these, 12 alien species were collected at 80% (12 of 15) of the sample sites; alien species represented about 38% of all species ($N = 32$) collected during the study. A total of 60% (9 of 15) of the sample sites had poor IBI scores. A minimum reach length of about 36 times MCW was determined to be sufficient for collecting an adequate number of fish for estimating biotic condition based on an IBI score. For most sites, this equates to collecting 275 fish at a site. Results may be applicable to other semiarid, fifth-order through seventh-order rivers sampled during summer low-flow conditions.

Regulatory agencies that are responsible for monitoring multiple water bodies need consistent and cost-effective sampling methods for accurately and precisely measuring biotic condition. Because collection methods and sampling effort vary widely among national and state assessment programs (Flotemersch et al. 2001) and because few studies have quantitatively evaluated the optimum electrofishing distance for large-river assemblages, no standard reach length has been accepted. Some scientists define sample reaches based on repeating geomorphic habitat features or meander wavelength to ensure that all habitats are represented within the reach (Frissell et al. 1986); others use multiples of mean channel width (MCW; wetted channel) of the stream as a scaling factor for stream size (Hughes et al. 2002; Angermeier and Smogor 1995).

An important issue surrounding the assessment of fish assemblages in large rivers (fifth-order through seventh-order; after Strahler 1957) is the minimum sampling distance required to determine biotic condition. Excessive sampling effort is costly in terms of work hours, reduces the number of sites that can be visited, can compromise field-crew safety, can be logistically unfeasible, and can cause unnecessary injury to captured fish. On the other hand, inadequate sampling effort can produce considerable variability in multiple samples collected at a site and may underrepresent the species or biotic condition present. Adequate sampling effort occurs when attributes of interest (e.g., species richness) approach an asymptotic level wherein additional sampling adds comparatively little new information (Lyons 1992). Evaluating the effects of electrofishing sampling effort is important in overall study design, development of site-scale sampling protocols, and quantification of ecological changes and patterns over time (Cao et al. 2001; Meador et al. 2003).

The index of biotic integrity (IBI)—based on a set of richness and guild metrics that together indicate biotic condition of a fish assemblage (Karr et al. 1986)—is increasingly being used to assess the ecological condition of water resources (Simon 1998; Brown et al. 2005). The IBI developed for northwest rivers ranges from 0 to 100 and is based on the sum of 10 equally weighted metrics (number of native coldwater species, number of alien species, number of salmonid age-classes, catch per unit effort or number of coldwater individuals collected per minute of electrofishing, percent sculpin individuals, percent sensitive native individuals, percent coldwater individuals, percent tolerant individuals, percent of individuals that are common carp *Cyprinus carpio*, and percent of individuals with selected anomalies; Mebane et al. 2003).

Differences in sample reach length can affect IBI scores, mainly through richness metrics, and can therefore result in erroneous stream assessments

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(Angermeier and Karr 1986; Dauwalter and Pert 2003). For these reasons, standardized sampling of fish is desirable for biomonitoring programs (Meador et al. 1993; Peck et al. 2002). However, sampling distances for a single boat electrofishing pass may vary regionally because of differences in fish species richness, variability in stream channels, and physical obstructions to boat travel (Meador 2005). A few investigations have evaluated electrofishing effort effects on the IBI; however, these were on wadeable streams. Reach lengths of 40–51 times MCW were prescribed to adequately score an IBI for Oregon and Ozark (Arkansas) streams (Dauwalter and Pert 2003; Reynolds et al. 2003). Karr et al. (1986) suggested sampling reaches of 11–15 stream widths to assess biotic integrity. That distance would include at least one meander wavelength in a sampling reach to ensure that representative habitats are sampled (Leopold et al. 1964). Hughes et al. (2002) recommended sampling 40–100 channel widths to ensure that the common geomorphic habitat units present in a river reach are represented. The U.S. Geological Survey (USGS) National Water Quality Assessment Program prescribes a two-pass boat electrofishing effort and a sampling distance of 500–1,000 m for large rivers (Meador et al. 1993), as well as the use of multiple gears (e.g., boat and backpack electrofishing) to more effectively sample different habitats within a representative reach. The U.S. Environmental Protection Agency (USEPA) rapid bioassessment protocols recommend sampling all habitats within a distance of 40 times the MCW of boatable waters (Flotemersch et al. 2001).

Recent publications have outlined large-river sampling protocols, fish species attributes, and IBI metrics to evaluate biotic integrity of large rivers of the Pacific Northwest (Zaroban et al. 1999; Grafe et al. 2002; Mebane et al. 2003). However, the minimum sampling effort required to consistently and accurately estimate the IBI was not provided.

Our primary objective was to determine a boat electrofishing effort (i.e., relative MCWs) that would produce IBI scores within 10% of those calculated from sampling of 40- and 100-MCW sites within a diverse set of randomly selected large rivers of southern Idaho. Effort was deemed sufficient when 90% of all simulated IBI scores for a reach were within 10% of final IBI scores. Minimum sampling effort was assessed by comparing the relation between reach length and the resulting change in IBI score. A secondary objective was to describe the current status of the fish assemblages in large rivers of southern Idaho. Information on the level of effort necessary to provide sufficient fish assemblage data will enable evaluation of the biotic condition of southern Idaho's large rivers.

Methods

Study area.—The study area (Figure 1) includes the Snake River and its major tributaries and the main-stem Salmon and Bear rivers in southern Idaho. The study area is located predominantly in the Snake River basin, High Desert, and Northern Basin and Range ecoregions (McGrath et al. 2001). Climate in most of the study area is semiarid and annual precipitation ranges from 25 to 50 cm. Precipitation occurs primarily as snow, and peak flows generally result from spring snowmelt. Range and forest land are the predominant land uses, and more than 60% of the land is federally owned. Populated areas and agricultural lands are located primarily adjacent to main stems and major tributaries, which provide water for irrigation and domestic uses.

Migrating fish face many obstacles along the Snake River. Shoshone Falls, near the city of Twin Falls, Idaho, is more than 65 m high and is a natural barrier to upstream movement of fish (Figure 1). Flow in the Snake River is highly regulated by dams and diversions; 18 large dams currently regulate the river (Maret and Mebane 2005). Pacific salmon *Oncorhynchus* spp., steelhead *O. mykiss*, and Pacific lampreys *Lampetra tridentata* were extirpated from the study area after construction of some of these large dams on the main-stem Snake River (Maret et al. 1997).

Most rivers in Idaho are presumed or explicitly designated to support coldwater biota (Maret and Mebane 2005). Rivers in predominantly rangeland and forested basins of southern Idaho are typified by coarse substrate (gravel and cobbles), a variety of low to moderate gradients (<0.1% to 0.6%), and generally sparse macrophyte growth. Rivers in agricultural basins typically have finer-grained substrata, low-gradient habitats, and abundant macrophyte growth. Sampling site elevations ranged from 670 to 1,850 m above sea level. Specific conductance ranged from 53 to 866 μS/cm for all sites. Because of drought conditions, southern Idaho river flows were about 60–80% of the long-term average during the sampling period (Brennan et al. 2003).

Sampling design.—At the request of Idaho Department of Environmental Quality (IDEQ), we sampled 10 (a representative number) nonwadeable southern Idaho rivers to evaluate the amount of effort required to accurately and precisely estimate the IBI for the fish assemblages. This consisted of a sampling distance study, whereby the selected rivers were sampled for fish from 15 study reaches representing 40 (12 sites) and 100 (3 sites) times MCW; these sites were selected via a spatially balanced randomized sample (Herlihy et al. 2000). The 10 selected rivers represented a diverse set of river sizes, anthropogenic

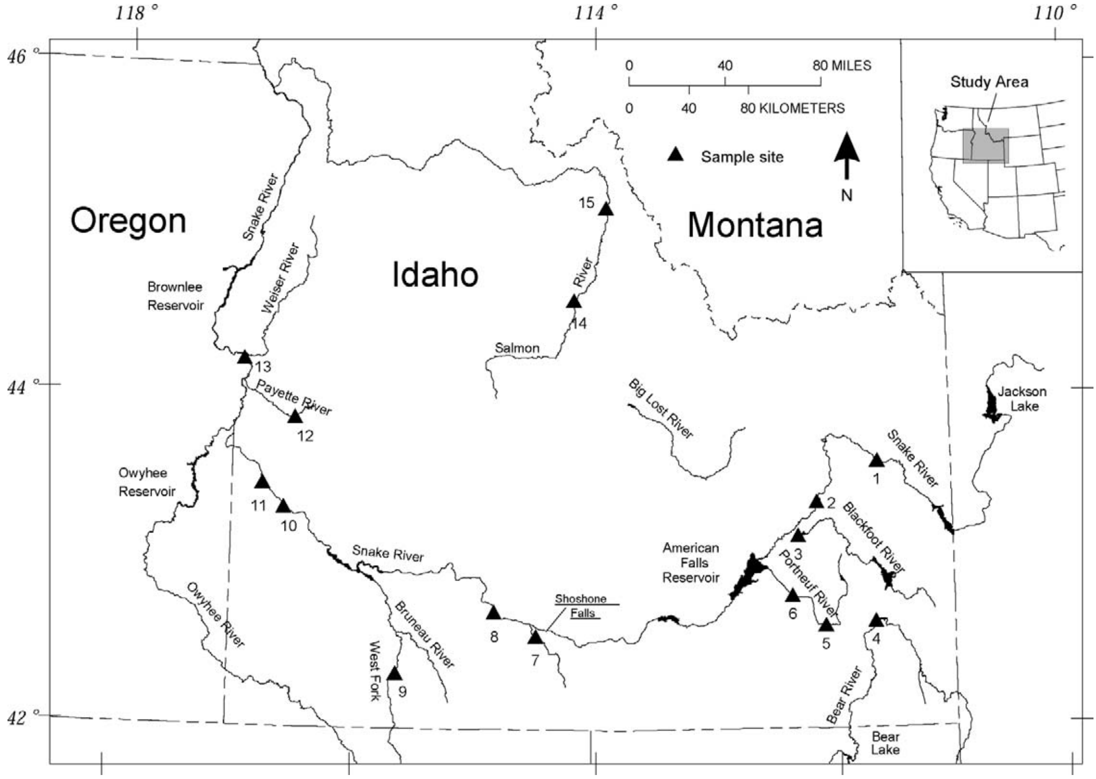

FIGURE 1.—Location of 15 randomly selected sample sites on 10 large rivers in southern Idaho that were electrofished in 2002 to examine biotic condition of the fish assemblages. Sites are described in greater detail in Table 1.

disturbance levels, and habitat conditions. Selected sites were fifth order or higher on 1:100,000-scale hydrographic maps (USGS 2004; Figure 1; Table 1). A field reconnaissance was conducted before sampling to determine access and reach lengths at each site. The sampling reach for site 1 was moved about 10 km upstream from the original randomly selected point to avoid river hazards. Within each study reach, we delineated 10 continuous electrofishing subreaches of equal length (i.e., length of each subreach was 4 or 10 × MCW) and sampled each to evaluate electrofishing effort and cumulative IBI scores. Data for each subreach were recorded separately to enable IBI calculations for each subreach and any combination of subreaches. Average percent differences were then calculated for the various combinations of subreaches relative to the final IBI score.

Topographical maps assisted in the determination of launch sites and landings that would bracket sample reaches. A laser rangefinder was used to measure stream widths at three or more locations representing a variety of geomorphic habitat features (i.e., riffle, pool, run) to determine the reach length to sample. A Global Positioning System unit was used to determine sampling locations for each subreach. Temperature, specific conductance, and dissolved oxygen were measured at each site with a YSI meter (Model 85M).

Fish collections.—Fish were collected at the large-river sites during low-flow conditions (July–October) in 2002 following modified protocols of the USEPA Environmental Monitoring and Assessment Program (Peck et al. 2002). All collections and identifications were made by the same team of experienced USGS personnel who were familiar with sampling protocols and fish species of Idaho. Meador and McIntyre (2003) noted that crew experience may be an important factor contributing to variability in fish assemblage sampling. All sampling was limited to 1 d/site, which included travel and collection time.

Two sites were selected to evaluate spatial and temporal variability in collection methods and final IBI score. A spatial replicate was taken at site 7, and fish were collected during the same week on different reaches of equal length that were about 2 km apart. A temporal replicate sample was taken at site 11 at the beginning and end of the summer.

TABLE 1.—Basin and site characteristics for large-river sample sites in Idaho, 2002. Sample sites representing reach lengths of 40 and 100 mean channel widths (MCWs) were electrofished to examine biotic condition of the fish population.

Site number[a]	Site name	Stream[b] order	Elevation (m above sea level)	Average MCW (m)	Reach length (m)	Total electrofishing time (s)	Specific conductance (μS/cm)
	40 MCW Sites						
2	Snake River near Shelley	6	1,400	130	5,200	3,466	287
3	Blackfoot River near Blackfoot	6	1,350	18	720	2,215	315
4	Bear River near Soda Springs	5	1,720	40	1,600	1,588	733
5	Portneuf River near Topaz	5	1,500	15	600	1,113	866
6	Portneuf River near Pocatello	5	1,350	12	480	1,226	681
7	Rock Creek at Twin Falls	5	1,100	8	320	1,603	683
8	Snake River at Hagerman	7	880	193	7,700	6,438	546
9	West Fork Bruneau River near Grasmere	5	1,140	14	560	1,724	147
10	Snake River near Walters Ferry	7	700	130	5,200	3,127	486
13	Weiser River near Weiser	6	670	25	1,000	2,088	286
14	Salmon River near Challis	6	1,490	40	1,600	1,315	242
15	Salmon River near Salmon	6	1,190	50	2,000	1,941	274
	100 MCW Sites						
1	Snake River at Heise	6	1,530	110	11,000	7,051	304
11	Snake River near Marsing	7	680	150	15,000	11,114	490
12	Payette River near Emmett	6	720	60	6,000	4,681	53

[a] Site numbers are indicated on the map in Figure 1.
[b] Based on 100,000-scale hydrography.

Fish were collected by a single netter in the bow of the boat while electrofishing in a downstream direction at a speed slightly faster than river velocity. The boat was equipped with a Smith-Root Model VI-A, DC pulsator and a 5,000-W, 240-V generator with bow-mounted anodes made of a circular array of 6.5-mm-diameter steel cable extending in front of the bow. Electrofishing (DC) usually varied between 30 and 60 pulses/s at 400–1,000 V and 2–4 A depending on conductivity and water temperature. We chose electrofisher settings that rolled fish and induced some observable electrotaxis of fish towards the anodes without causing noticeable external injury. Electrofishing time (i.e., electric current applied to water) ranged from 0.3 to 1.8 h for the 40-MCW sites and from 1.3 to 3.1 h for the 100-MCW sites.

Electrofishing was concentrated near riverbanks. Where possible, after two consecutive subreaches were sampled, collections were switched to the opposite bank. This ensured that habitats from both banks were

TABLE 2.—Summary of index of biotic integrity (IBI) metrics and final scores and three other fish collection metrics for 15 sites in 10 large rivers in southern Idaho, 2002.

Metric	Site number[a]														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
IBI metrics															
Number of coldwater native species	4	4	1	1	1	2	2	1	2	0	0	2	0	5	3
Percent sculpins	3.0	6.0	7.0	4.0	1.0	6.0	9.0	0.0	7.0	0.0	0.0	1.0	0.0	4.0	2.0
Percent sensitive native individuals	12.0	1.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	1.0	0.0	7.0	1.0
Percent coldwater individuals	98.0	21.0	7.0	4.0	2.0	7.0	35.0	1.0	9.0	0.0	0.0	17.0	0.0	62.0	33.0
Percent tolerant individuals	1.0	26.0	52.0	24.0	28.0	62.0	31.0	94.0	25.0	52.0	47.0	41.0	35.0	31.0	45.0
Number of alien species	3	5	1	2	2	4	3	2	0	4	4	3	9	0	0
Percent common carp individuals	0.0	0.3	12.2	14.2	28.3	0.8	0.4	1.5	0.0	18.1	12.1	6.6	2.4	0.0	0.0
Catch per unit effort[b]	8.7	1.3	0.3	0.5	0.3	1.3	3.3	0.1	0.7	0.0	0.0	1.6	0.0	8.5	2.9
Percent selected anomalies[c]	0.0	0.0	0.6	0.8	0.0	0.0	0.4	0.0	0.0	0.2	0.0	0.0	2.4	0.0	0.4
Final IBI score	76.0	54.3	19.4	27.3	26.0	34.2	56.7	29.0	53.8	11.6	14.0	35.0	12.1	74.9	60.6
Other metrics															
Number of fish collected	1,050	358	164	394	304	358	260	581	214	409	967	692	82	300	283
Number of native fish species	7	8	7	4	4	6	6	5	10	4	3	8	5	11	10
Total number of fish species	10	13	8	6	6	10	9	7	10	8	7	11	14	11	10

[a] Site numbers are identified on the map in Figure 1.
[b] Number of coldwater individuals collected per minute of electrofishing.
[c] Includes deformities, eroded fins, lesions, and tumors.

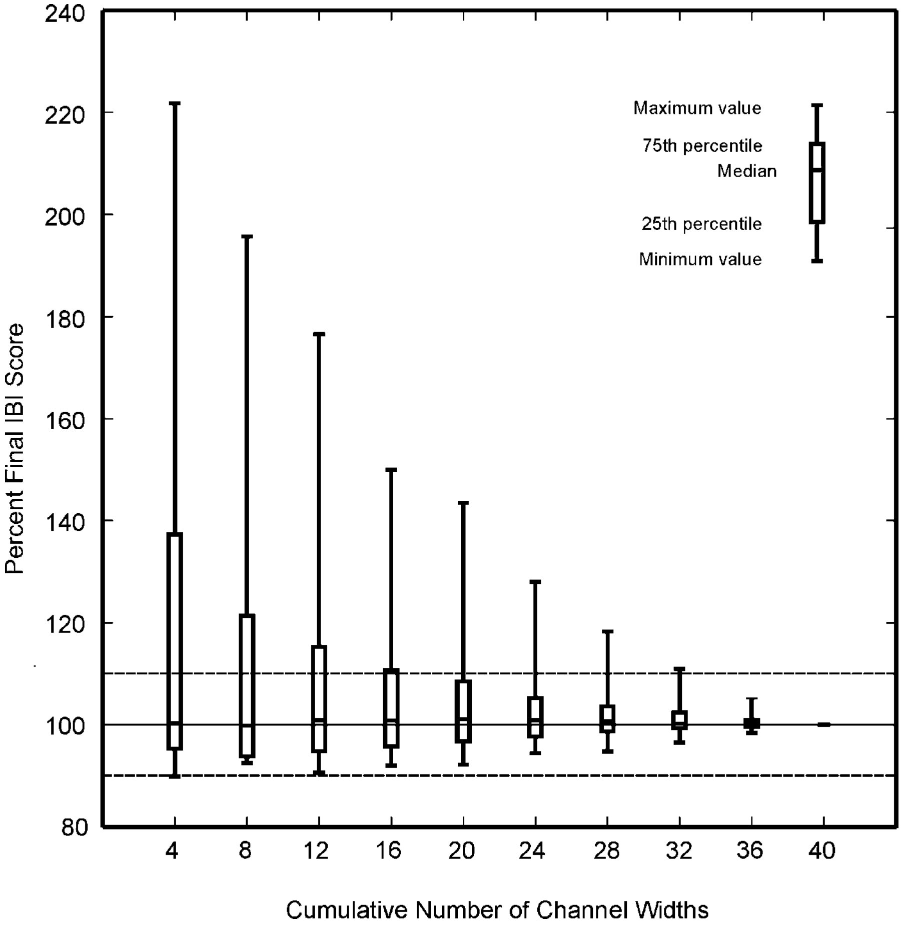

FIGURE 2.—Percentage of the final index of biotic integrity (IBI) score for an electrofished reach length equal to 40 mean channel widths (MCWs) plotted in relation to cumulative sampling distance within the reach (combinations of between 1 and 10 subreaches, each 4 MCWs long) for 12 large-river sites in southern Idaho, 2002. Results are based on the means of 500 Monte Carlo simulations for each number of subreaches at each site. Dashed lines denote IBI scores within 10% of the final score.

sampled throughout the reach. Attempts were made to capture all fish species from habitats at each sampling site.

To reduce fish stress, captured fish were placed in an aerated live well and processed immediately after sampling of each subreach. All fish were identified to species, counted, and measured (minimum and maximum total length). Specimens of selected species were retained for reference and verification of field identifications. Individuals that were too large for collection jars were photographed before being released to the river. A voucher collection from these samples is located in the Orma J. Smith Museum of Natural History, Albertson College, Caldwell, Idaho. Donald W. Zaroban, fish curator for the museum, provided taxonomic confirmation for selected specimens.

Data analyses.—We calculated IBI scores as described by Mebane et al. (2003) for each reach and each random combination of subreaches (10 × MCW). We did not collect data to determine salmonid age; therefore, we calculated IBI scores for the remaining nine metrics. Each metric was standardized to a score of 0–10, and IBI scores were standardized to score from 0 to 100. According to Mebane et al. (2003), IBI scores delineate three levels of biotic condition: a score of 75–100 represents high biotic condition, minimal disturbance, and an abundant, diverse assemblage of native coldwater species; a score of 50–74 represents somewhat lower biotic condition, greater frequency of alien species, and a predominance of coolwater native species; and a score less than 50 represents poor biotic condition, a paucity or absence of coldwater and sensitive species, and a predominance of tolerant fishes.

TABLE 3.—Mean percent of final index of biotic integrity (IBI) score versus sampled reach length (in mean channel widths [MCWs]) based on 500 Monte Carlo simulations at each composite sample size for 12 southern Idaho river sites, 2002. Sites represent electrofishing effort of 40 times MCW. Bold numbers denote IBI scores exceeding ±10% of the final score.

Site	Reach length (MCWs)										Final
number[a]	4	8	12	16	20	24	28	32	36	40	IBI score
2	**89.9**	92.5	94.6	95.4	96.4	97.3	98.4	99.2	99.5	100	54.3
3	**140.8**	**122.1**	**115.4**	**110.1**	107.7	105.3	103.5	102.5	101.0	100	19.4
4	94.6	95.0	95.6	96.8	98.5	99.0	99.5	99.7	99.9	100	27.3
5	108.5	93.8	91.0	92.9	93.3	95.2	94.8	96.5	98.4	100	26.0
6	**126.8**	**119.3**	**114.9**	**110.9**	108.7	105.2	103.6	102.2	100.9	100	34.2
7	98.4	99.1	101.3	100.3	100.9	101.9	101.8	100.9	100.5	100	56.7
8	100.8	93.3	90.6	92.0	92.2	94.4	96.7	97.0	98.6	100	29.0
9	90.8	93.8	95.6	97.4	97.8	98.9	99.6	99.7	100.0	100	53.8
10	**186.8**	**146.9**	**131.3**	**119.0**	**112.9**	109.5	106.4	103.2	102.0	100	11.6
13	**221.8**	**195.7**	**176.6**	**150.0**	**144.1**	**130.4**	**124.0**	**111.0**	108.1	100	12.1
14	99.7	102.6	101.8	101.3	101.2	100.6	100.5	100.1	100.0	100	74.9
15	97.5	100.5	100.6	101.4	101.4	101.3	100.8	100.3	100.4	100	60.6

[a] Site numbers are identified on the map in Figure 1.

We used a Monte Carlo simulation analysis to sample random, hypothetical combinations of subreaches (1–10) for calculation of an IBI score and species richness for each of 500 simulations (Manly 1991). This approach provides a more robust examination of variation and is free from bias associated with the choice of a starting point (Angermeier and Smogor 1995; Reynolds et al. 2003). For example, we randomly picked two subreaches without replacement and calculated an IBI score, and this was repeated 499 times. This procedure was done 500 times for all possible number of subreaches (i.e., from 1 to 10 subreaches) in the reach. For each reach, the results for each simulated number of subreaches were averaged (e.g., all two-subreach scores) to represent an average rate of change in the IBI score or species richness with successive sampling effort.

The final IBI score for each site was calculated using all available data (all subreaches within the site). Sampling effort was evaluated by calculating the percent difference from the final IBI score for each subreach composite sample size. This provided a count or percentage of sites that were within 10% of the final IBI score as each subreach was added. Because species richness is an important component of IBI metric scoring, we also constructed cumulative species richness curves for sites to evaluate information gained with successive effort.

Results

Fish Assemblage

We collected 32 fish species in the families Catostomidae, Centrarchidae, Cottidae, Cyprinidae, Ictaluridae, Percidae, and Salmonidae. The most commonly collected species (collected at 10 or more sites) were mottled sculpin *Cottus bairdii*, common carp, and speckled dace *Rhinichthys osculus*. The number of fish collected at all sites ranged from 82 to 1,050 (Table 2). One or more alien species were collected at 80% (12 of 15) of the sample sites. Only sites 9, 14, and 15 were composed entirely of native species. The IBI scores varied widely, ranging from 12 to 76 for all sites. A mean IBI score of 39 for all sites indicates that large rivers in southern Idaho are generally in poor biotic condition, despite the relatively high percentage of public land. Species richness ranged from 6 to 14 for all sites. Site 13 had the most species, although the IBI score was 12.1. This site also had the fewest individuals of all sites and was

TABLE 4.—Mean percent of final index of biotic integrity (IBI) score versus sampled reach length (in mean channel widths [MCWs]) based on 500 Monte Carlo simulations at each composite sample size for three southern Idaho river sites, 2002. Sites represent electrofishing effort of 100 times MCW. Bold numbers denote IBI scores exceeding ±10% of the final score.

Site	Reach length (MCWs)										Final
number[a]	10	20	30	40	50	60	70	80	90	100	IBI score
1	97.3	97.1	98.1	98.3	98.9	99.4	99.6	99.9	100.0	100	76.0
11	**136.4**	**114.0**	108.0	105.2	103.3	102.3	101.8	101.1	100.6	100	14.0
12	98.8	97.5	96.5	97.5	96.8	97.2	98.4	98.4	98.9	100	35.0

[a] Site numbers are identified on the map in Figure 1.

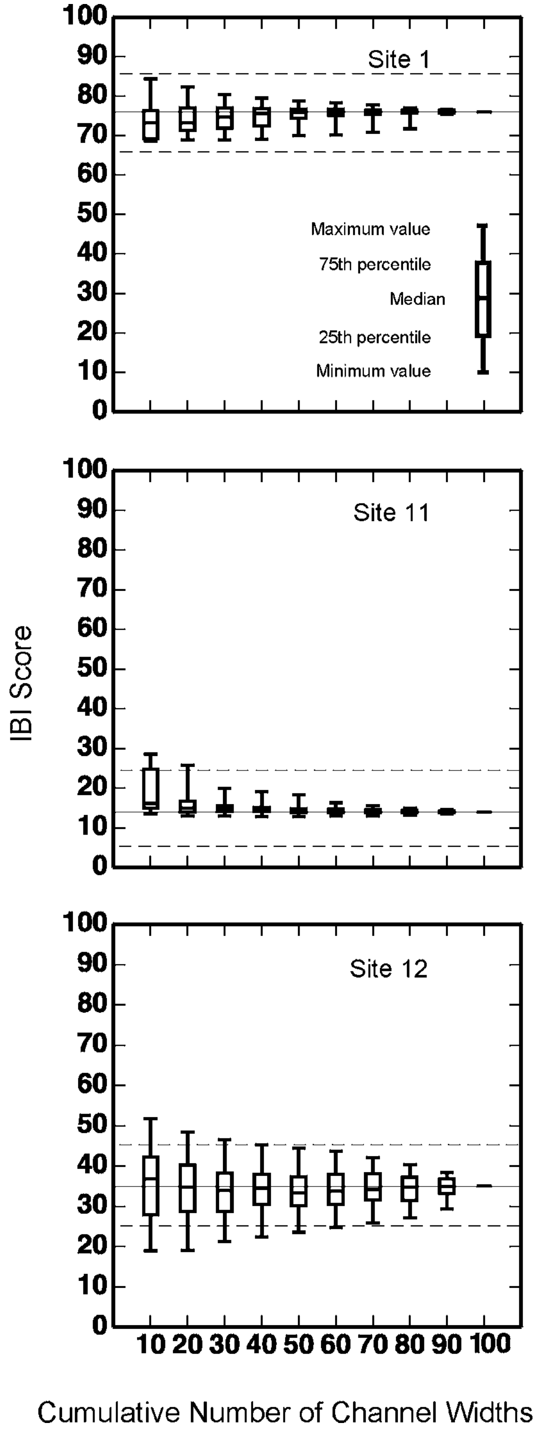

FIGURE 3.—Index of biotic integrity (IBI) scores for an electrofished reach length equal to 100 mean channel widths (MCWs) plotted in relation to cumulative sampling distance within the reach (combinations of between 1 and 10 subreaches, each 10 MCWs long) for three large-river sites in southern Idaho, 2002. Results are based on 500 Monte Carlo simulations for each number of subreaches at each site. Dashed lines denote IBI scores within 10% of the final score.

composed entirely of warmwater tolerant species, nine of which were alien.

A summary of IBI scores and component metrics reveals a decline in main-stem Snake River IBI scores from upstream to downstream (Table 2). Sites 1, 2, 8, 10, and 11 had IBI scores of 76, 54, 29, 12, and 14, respectively. A total of 60% (9 of 15) of the sites had poor IBI scores, and 80% of the sites had one or more alien species. Final IBI scores for the spatial and temporal replicate samples were 56.7 and 69.1 at site 7 (spatial replicates) and 14.0 and 5.4 at site 11 (temporal replicates). Snake River site 10, which is only about 20 km upstream of site 11, had a comparable IBI score of 11.6 (Table 2).

Sampling Effort

Based on Monte Carlo analysis, IBI scores for the 40-MCW sites appeared to stabilize after 20 MCWs (Figure 2). At 20 MCWs, the interquartile range was within 10% of the final IBI score. At 24 MCWs, only one site (site 13) had a score that was beyond ±10% of the final score (Table 3). Site 13 had a low abundance of fish, and the assemblage was primarily composed of tolerant warmwater aliens. All sites, on average, were within 10% of the final IBI score when the sampling distance was 36 times MCW. A number of sites with relatively low final IBI scores (sites 3, 6, 10, and 13) had higher scores in many of the initial subreaches, as indicated by the high percent differences (Table 3).

Monte Carlo-simulated mean IBI scores at 30 MCWs for sites 1, 11, and 12 (100 × MCW) were all within 10% of the final IBI score (Table 4). The IBI scores determined from the Monte Carlo simulations at 30 MCWs for sites 1 and 11 were all within 10% of the final IBI score (Figure 3). Site 12 exhibited more variability; most simulated IBI scores were within 10% of the final IBI score when the sampling distance was 40 MCWs. This site had a mix of coldwater native and alien species, which increased the variability of the IBI.

From the Monte Carlo analyses, more than 90% of the species richness at 40 MCWs was also captured by sampling 32 MCWs (Figure 4). However, species richness was still increasing beyond 40 MCWs. Simulated cumulative species richness for sites sampled at 100 MCWs confirms that effort levels beyond 40 MCWs yield additional species (Figure 5).

Mean catch rates (i.e., fish captured per subreach) were similar among subreaches (Figure 6). The mean (±SE) catch rates were 31.0 ± 2.3 fish/subreach (N = 12) for the 40-MCW reaches and 90.3 ± 10.9 fish/

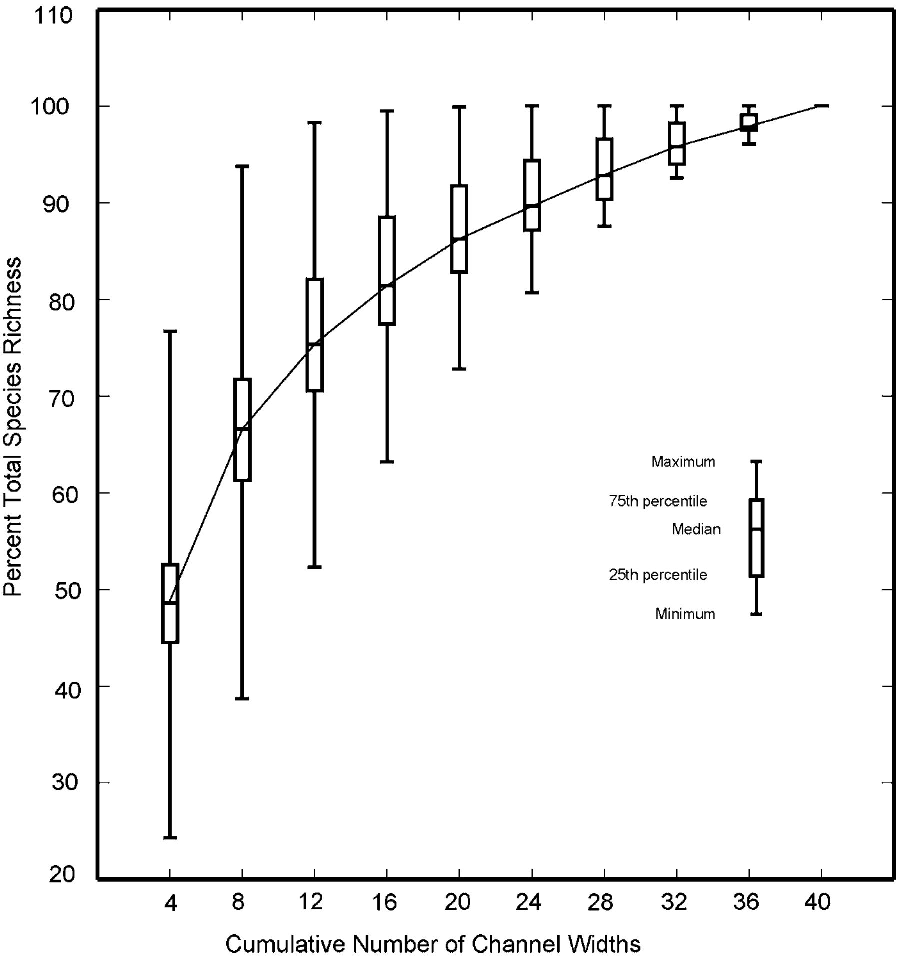

FIGURE 4.—Percentage of the total species richness for an electrofished reach length equal to 40 mean channel widths (MCWs) versus cumulative sampling distance within the reach (combinations of between 1 and 10 subreaches, each 4 MCWs long) for 12 large-river sites in southern Idaho, 2002. Results are based on the means of 500 Monte Carlo simulations for each number of subreaches at each site. The solid line connects median values.

subreach ($N = 3$) for the 100-MCW reaches. The mean number of fish collected per subreach for 40-MCW sites ranged from 25 fish at 4 MCWs to 300 fish at 40 MCWs.

Discussion

Fish Assemblage

We collected 12 alien species, representing about 38% of the 32 observed species. Many of these alien species (e.g., sunfish, common carp, and catfish) are adapted for warm waters, especially those created by impoundments. The common carp, a tolerant alien species, was collected at about 73% (11 of 15) of the sites. Sites with common carp were typically composed of few or no coldwater or sensitive fish species. According to Mebane et al. (2003), the presence of common carp indicates degraded conditions in Pacific Northwest rivers.

Sampling Effort

In our judgment, the IBI evaluated in this study is a robust evaluation tool to estimate biotic condition of rivers in arid regions of the Pacific Northwest. The IBI scores we obtained were expected given the river conditions and habitat available. Replicate samples were precise for two Snake River sites about 22 km apart, indicating poor biotic condition (scores of 11.6–14.0). In addition, IBI scores estimated for 30–40 MCWs were generally similar to those for 100 MCWs, indicating that they are reasonably accurate.

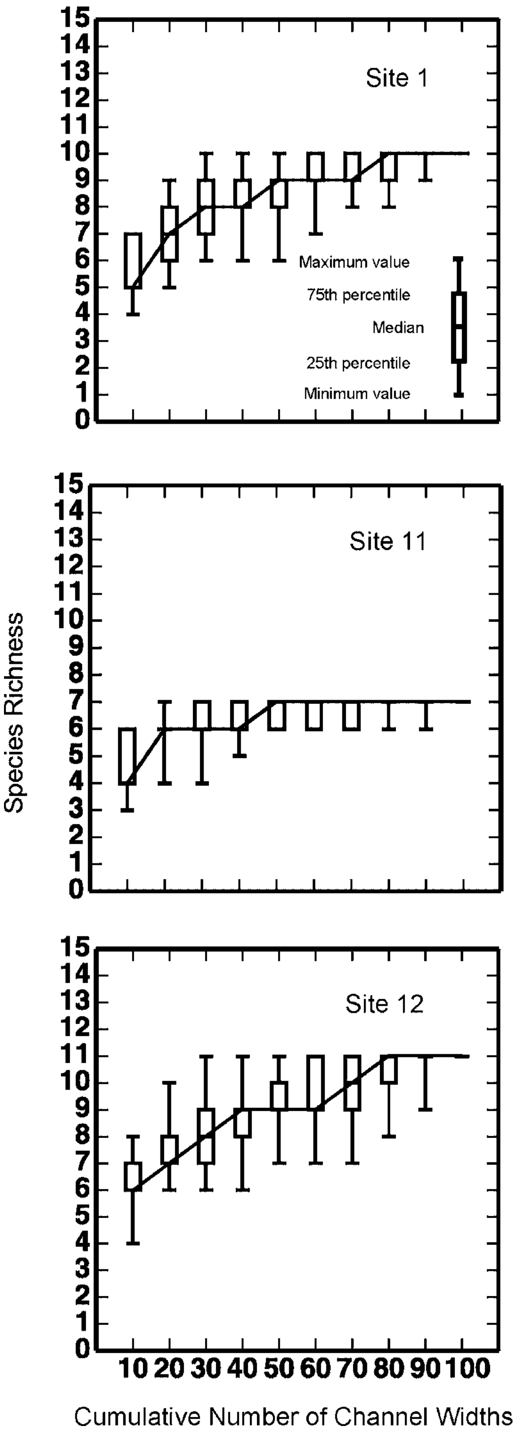

FIGURE 5.—Species richness for an electrofished reach length equal to 100 mean channel widths (MCWs) versus cumulative sampling distance within the reach (combinations of between 1 and 10 subreaches, each 10 MCWs long) for three large-river sites in southern Idaho, 2002. Results are based on 500 Monte Carlo simulations for each number of subreaches at each site. The solid line connects median values.

Our data corroborate the findings of Dauwalter and Pert (2003) and Reynolds et al. (2003), who determined that the IBI is affected by sampling effort. Scores for sites sampled at 40 times MCW stabilized at about 20 MCWs; at 36 MCWs, scores were all within 10% of the final score. Monte Carlo simulation results for three sites sampled at 100 times MCW support these results: almost all IBI scores were within 10% of final scores as the sampled reach length approached 40 MCWs. The weight of evidence in this study indicates that sampling of 36 MCWs is sufficient for collecting an adequate number of fish to estimate biotic condition based on an IBI score. This reach length is slightly less than the 50 MCWs that Hughes and Herlihy (2007) determined from 45 raftable rivers in Oregon.

Our study indicated that 90% of the fish species captured in a reach length of 40 MCWs is also captured within a 32-MCW reach. This is substantially less than the 85 MCWs needed to capture 95% of the fish species sampled from 100-MCW reaches in Oregon rivers (Hughes et al. 2002). The increasing slope of the species–effort accumulation curve (i.e., lack of asymptote) for 40-MCW sites suggests that further sampling is desirable to more accurately estimate species richness. In addition, our three 100-MCW sites provide further evidence that one or two rare species were captured beyond this distance. However, our results suggest that it is not necessary to collect a few rare species to accurately estimate the IBI. Paller (1995) determined that eliminating sporadically occurring rare fish species (relative abundance from <1% to 3%) reduced the reach length necessary to represent species richness by 63%.

Sites with poor IBI scores exhibited the highest variability in IBI subreach scores. A number of factors may explain why sites with initially high IBI scores subsequently produced relatively low scores (<35). First, the potential percent difference would be higher for sites with lower IBI scores relative to sites with high scores. In addition, metrics with a negative influence on the final IBI score (e.g., percent common carp, number of alien species, and percent tolerant species) can increase the IBI score if those species are absent in one or more subreaches. Regulatory agencies concerned with evaluating these types of waters may desire to sample longer reaches to ensure accurate characterization.

The adequate sampling effort of 36 MCWs is contingent on a catch rate similar to the rate we achieved. Based on a median channel width of 40 m for all sites sampled in this study, this would equate to a sample reach of about 1,440 m. This distance is similar to the 1,600-m sampling distance recommended for large rivers in Wisconsin (Lyons et al. 2001). This

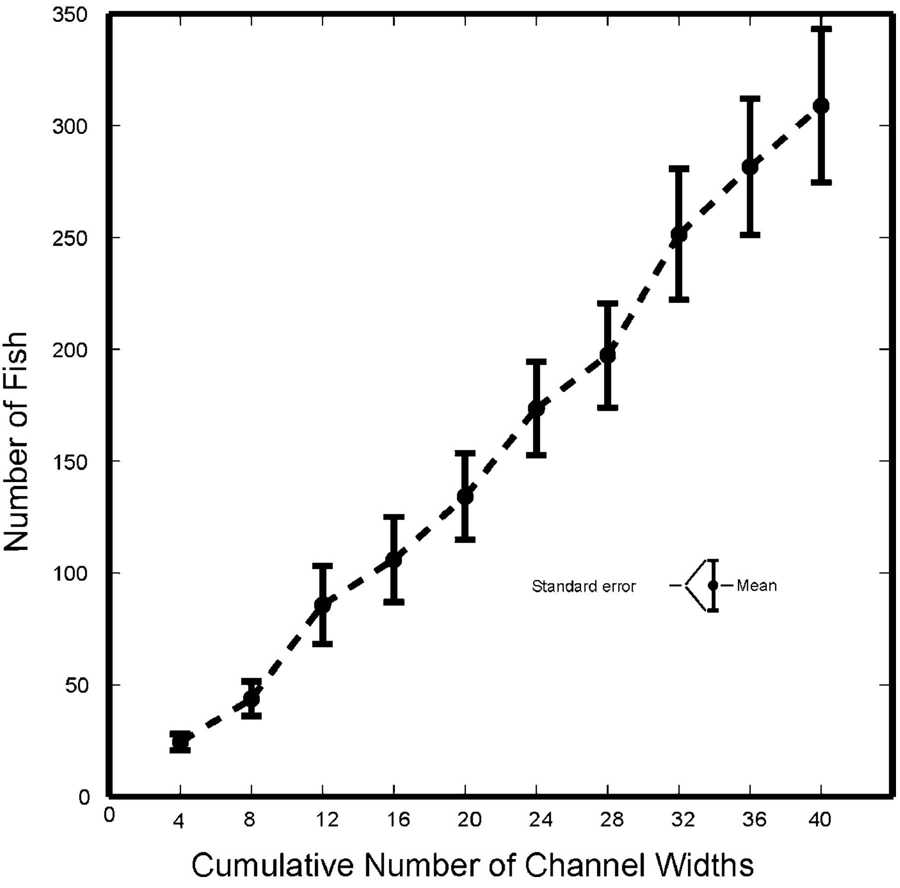

FIGURE 6.—Mean (±SE) number of fish collected in an electrofished reach length equal to 40 mean channel widths (MCWs) versus cumulative sampling distance within the reach (combinations of between 1 and 10 subreaches, each 4 MCWs long) for 12 large-river sites in southern Idaho, 2002.

reach distance can generally be electrofished by boat within 1 d. Based on our average capture rate, this would equate to about 275 fish captured from a sample reach of 36 MCWs. It is important to note that alternatives that include sampling a shorter reach distance may be required because of boat travel restrictions from river hazards, dams, or point source assessment. In these cases, increased sampling effort in a shorter reach using multiple gears or multiple passes may be necessary to collect a representative fish sample (Meador 2005). However, Paller (1995) determined that, when estimating fish species richness, it was more efficient to sample a large area with one pass than to sample a smaller area with many passes. In most cases when boat access is confounded by hazards, adjusting the sample reach downstream to account for the unsampled area would be a reasonable alternative.

Our results suggest that catch rates vary regionally. Mean catch rates determined for the sites we sampled were more than three times higher than the catch rate of about 25 fish per 10-MCW subreach in Oregon rivers (Hughes et al. 2002). Reasons for this large difference are unclear but could be involve differences in river habitat (i.e., higher slope), as the number of species collected was similar to that in our study. The mean slope reported by Hughes et al. (2002) was 0.8%, which is higher than that of all the sites we sampled. Capture efficiency in our study would be higher because slow-water habitats were more abundant.

A predetermined sampling effort is desirable for standardization of monitoring and assessment programs; however, our results show there can be differences among sites in the amount of effort (i.e., stream reach length) needed to adequately estimate IBI scores. Angermeier and Smogor (1995) suggested that discontinuous spatial distributions of species strongly influence the sampling effort needed to characterize fish assemblages and may limit development of a standard sampling effort. An interactive approach that avoids over- and undersampling may be more cost-effective. For example, our findings suggest an absolute minimum of 20 MCWs should be sampled for the IBI score to stabilize. This minimum distance would include multiple riffle–pool sequences for most natural alluvial channels, thus providing multiple opportunities to capture fish in a variety of available habitats. Additional sampling effort (e.g., at 5-MCW sample units) to precisely estimate the IBI within an acceptable range could then be determined on site by a field crew using new technology such as a field laptop or pocket computer. Cao et al. (2001) offers a similarity-based approach that could be useful to evaluate fish sampling sufficiency in the field.

We are confident that sampling distance estimates developed in our study are representative of southern Idaho rivers because reaches were randomly selected from 1:100,000-scale hydrographic maps of large rivers. Our results are applicable to other semiarid, fifth-order through seventh-order rivers sampled during summer low-flow conditions. Our findings may not apply elsewhere, especially if fish faunas, habitats, and sampling methods differ. These findings are also specific to the IBI we evaluated and may not apply to other IBIs with different metrics. Ultimately, our results contribute to a better understanding of the level of sampling effort needed to characterize fish assemblages of large rivers.

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